THE RELATIONSHIP BETWEEN DEGREE OF DONENESS AND END-POINT TEMPERATURES OF ROASTED TURKEY HALVES

by

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INTRODUCTION

It is difficult to roast turkey consistently to a satisfactory degree of doneness. Recommendations are needed for an objective means of determining the end-point of cooking that will produce regularly a roasted turkey of optimum doneness.

Several criteria that have been suggested for determining the end-point for roasting turkey are: (1) roasting to a given internal temperature in the thigh, breast or stuffing; (2) roasting for a certain number of minutes per pound of bird; and (3) subjective observations such as appearance (color and dryness) of the bird, feel of the flesh, ease of moving the joints and ease of pricking with a fork. None of these methods for determining doneness consistently give reproducible results. However, unpublished data from this laboratory indicate that roasting to a given internal temperature in the thigh or in the breast seems promising as an index to doneness of roasted turkey.

The purpose of this study was to compare the degree of doneness of frozen defrosted turkey halves roasted to internal temperatures of 85° and 90° C. in the breast and 90° and 95° C. in the thigh muscles. Physical measurements for degree of doneness of the birds cooked to these four end-points should provide beneficial data in the development of a standard method of roasting turkeys.

REVIEW OF LITERATURE

The physical and chemical composition of meat is altered during the cooking process. The changes that take place in muscle

during roasting are dependent largely upon the degree of doneness to which the meat is cooked. To understand more fully these alterations in meat during the cooking process, a discussion of the composition of poultry muscle follows.

Physical Composition of Poultry Muscle

Skeletal muscle is made up of bundles of fibres, the fasciculi, held together by connective tissue, the perimysium, and surrounded by a muscle sheath, the epimysium. The fibers of the fasiculi run parallel to each other and each one is enclosed in a thin elastic membrane, the sarcolema. According to Lowe (1955) these fibers are composed of fibrils that are roughly one micron in diameter.

The three components of connective tissue are collagenous fibers, elastic fibers, and a ground substance or matrix (Lowe, 1955). The collagenous fibers are colorless, birefringent, slender, often curly, and have little elasticity, whereas elastic fibers are more slender, highly birefringent and have great elasticity. The ground substance was described by Miller and Kastelic (1956) as an adhesive matrix that held the strands of collagen and elastin. Connective tissue is characterized by a small number of cells, much intercellular substance and many forms and variations in degree of looseness or compactness of fibers (Lowe, 1955).

Chemical Composition of Poultry Muscle

Proteins, fat and water are the major constituents of poultry muscle listed by Lowe (1955). Small amounts of inorganic and

organic salts, pigments, nitrogenous and non-nitrogenous extractives, carbohydrates, enzymes and vitamins also are present.

Muscle Proteins. Lowe (1948) reported that two types of protein are present in muscle: the intracellular or protoplasmic proteins that consist of myosin and a non-myosin fraction and the intercullular or structural proteins that consist mainly of collagen and elastin. Intracellular proteins are soluble in certain concentrations of salt solutions, whereas structural proteins are characterized by their insolubility in salt solutions. The intracellular myosin was described by Szent-Gyorgyi (1948) as an inactive skeleton to which were attached a number of globular proteins; without these it was inactive and did not contract. These globular proteins were called protins to distinguish them from other muscle proteins. The non-myosin fraction of the protoplasmic proteins is made up of myogen, globulin X and myoalbumen (Bate-Smith, 1949). These differ in solubility and isoelectric point. Collagen, an intercellular protein, was considered by Astbury and Bell (1940) to be similar in chemical composition to gelatin. They further noted that about one-third of all the amino acid residues present in gelatin were either proline or hydroxyproline. The ground substance was reported by Miller and Kastelic (1956) to consist mainly of mucopolysaccharides and mucopolysaccharide-protein complexes present in different degrees of polymerization.

Both intracellular and intercellular proteins are composed of amino acids linked together to form polypeptide chains. These chains, in turn, are bound together by cross linkages such as salt

bridges and hydrogen bonds. The properties of proteins are closely related to their structure; for example, upon denaturation hydrogen bonds are broken.

Effect of Heat on Protoplasmic Proteins. Heat coagulation of proteins was defined by Bull (1949) as a three-step process. The first step, denaturation, in which the protein molecule opens up and makes the sulfhydryl of the side chains detectable; the second, flocculation, results in a soluble flocculum; and the final step, coagulation, forms an insoluble coagulum by polymerization of the denatured protein molecule.

Coagulation of a protein is affected by the pH, the amount of water present, the presence and concentration of salts, the temperature of the protein and the length of time the protein is held at a given temperature (Lowe, 1955). Pence et al. (1953) concluded from their work that both pH and temperature have a complex relationship with the rate of denaturation. These workers noted that denaturation of wet gum gluten was slow at a pH of 4, but more rapid at higher pH values. They observed that at temperatures of 80° or 90° C. specific moisture levels permitted certain amounts of denaturation to occur. It was reported by Levy and Bengalia (1950) that the rate of denaturation of ricin was a simultaneous function of temperature and pH and that salt concentrations also significantly affected denaturation. Gibbs (1952) theorized that protein exists in several stages of dissociation and said that alteration of the pH increases ionization of side chain groups; therefore, the heat of denaturation varies with the state of ionization of the protein.

Lowe (1955) reported that there was no unanimity of opinion concerning the coagulation temperature of the various intracellular proteins. Coagulation of protoplasmic proteins probably occurs to some extent at 60° C. in that meat becomes firmer and the color changes when this internal temperature is reached. It is true that the rate of coagulation increases with an increase in temperature, but the temperature reached and the time the protein is held at that temperature cannot be considered apart. Protein coagulation is an endothermic process, and thus the internal temperature of meat cooked at low oven temperatures often remains stationary for several minutes between 75° C. and 80° C. Doneness of the meat is closely related to the extent of protein coagulation. The temperature lag varies in different birds and consequently a greater degree of doneness is observed at a lower internal temperature in some birds than in others (Lowe, 1955).

Effect of Heat on Structural Proteins. In the presence of heat and water some of the collagen in meat is converted to gelatin (Lowe, 1955). Since the water content of all meat is rather high, some collagen is broken down even when dry heat methods of cooking are used. The rate of conversion of collagen to gelatin is affected by the temperature reached, the pH of the solution, the size of the pieces and the kind of collagen. Winegarden et al. (1952) reported that collagen strips shortened in length and width, became thicker and had a tendency to curl when heated at temperatures ranging from 60° to 90° C. The optimum pH range for the conversion of collagen to gelatin was either between a pH of 3 and 4 or between a pH of 7.5 and 8.5 (Bogue, 1923). Elastin

is more stable than collagen and is changed to a lesser degree in the presence of heat and water.

Fat in Muscle. The fat content of turkey muscle was reported by Holcomb and Maw (1934) to be inversely proportional to the moisture content. Fat cells, polyhydral in shape, are deposited between the muscle fibers after sufficient numbers are formed in the perimysium, epimysium and areas surrounding the internal organs. The amount of fat deposited between the muscle fibers varies from muscle to muscle. Harshaw et al. (1943) found that the leg of Broad Breasted Bronze turkeys contained from two to three times more fat than the breast muscle and in most cases females had a higher fat content in the leg than did the males. Goertz et al. (1955) observed that the fat cells of the gluteus primus muscle were present in small groups, well distributed throughout the entire muscle. In the pectoralis major muscle, fat cells occurred in large clusters and concentrated in a few areas.

The amount and distribution of fat may affect the rate of cooking. When the muscle is heated, the connective tissue surrounding the fat cell breaks down and the melted fat escapes. It was reported by Thille et al. (1932) in their work with beef that the change in the heat conductivity of the fat as it passed from solid to liquid tended to speed up the rate of heat penetration in the case of exterior fat but had the opposite effect for interior fat.

Muscle Pigment. Myoglobin is the pigment that gives muscle its purplish-red color. According to Lowe (1953) myoglobin is

darker at a higher pH than at a lower pH. Its concentration is affected by the age of the animal and by the amount of exercise that the animal has undergone. A variation in the amount of myoglobin present in different muscles was noted by Lawrie (1950) who indicated that the leg muscle of poultry contained about 10 times more of this pigment than the breast muscle. This undoubtedly accounted for the color difference in these muscles. This worker also found no relationship between myoglobin and the nutritional state of the animal.

During heating, the muscle pigments undergo color changes (Lowe, 1955). After a temperature of 50° C. is reached, the bright red color changes gradually to a lighter color, and after a sufficiently high temperature is reached it turns to brown or gray. The bright red pigment, oxymyoglobin, is formed when myoglobin combines with the oxygen of the atmosphere. Oxymoglobin is converted to hematin when meat is heated.

Factors Affecting Rate of Heat Penetration

The rate of heat penetration in turkey during roasting is affected by several factors such as the time of chilling after slaughter, the muscle in which the temperature is measured, the position of the thermometer or thermocouple within the muscle, the initial temperature of the bird and the oven temperature. Also, there is some evidence that frozen, defrosted turkey cooks at a different rate from fresh chilled birds. It was suggested by Alexander et al. (1951) that a thorough study of rate of heat penetration is needed before recommendations for end-point

temperatures of roasted turkeys can be made. In a study of this type, Iacono et al. (1956) noted the rate of heat penetration in various muscles of a defrosted turkey. The thermocouples placed in the right breast showed that 240 minutes were required to reach an end-point of 185° F. The left rear breast muscles required only 197 minutes, the right drumstick, 207 minutes, and the left thigh, 216 minutes to reach this same end-point.

Initial Temperature of the Bird. Lowe (1955) reported that a longer cooking time was required when the initial temperature of the meat was low than when it was high. Meat with an initial temperature between 0° and 5° C. required longer cooking time than meat that had an initial temperature of 20° C. It was found by Iacono et al. (1956) that a frozen turkey needed a third longer to roast than a defrosted turkey when the same internal temperature was used for the end-point of cooking. Castellani et al. (1953) defrosted birds for eight hours at room temperature and overnight in the refrigerator before roasting and stated that the initial temperature exerted an appreciable effect on cooking time. These workers suggested that for frozen stuffed birds, the roasting time might be more than two times that required for unfrozen unstuffed birds.

Fresh Chilled versus Defrosted Birds. Marsden et al. (1952) suggested that the rate of heat penetration differs in the roasting of chilled and frozen defrosted birds. These workers roasted fresh chilled turkeys in one study and frozen defrosted turkeys in another to the same subjective end-point. They noted from these two investigations that the cooking time in minutes per

pound was less for the defrosted than for the fresh chilled birds. This might be explained, in part, by the partial denaturation of the muscle protein and the opening up of the muscle structure during freezing, thus allowing for a faster rate of cooking.

Oven Temperature. Various oven temperatures have been used for roasting turkey. A low temperature of 225° F. was reported by Alexander et al. (1948) for turkeys under 10 pounds. They used temperatures of 255 to 269° F. for heavy birds, i.e., those over 23 pounds, and 275° to 300° F. for intermediate weight birds. The average cooking time was 21.9, 24.0 and 23.6 minutes per pound for light, intermediate and heavy birds, respectively.

An oven temperature of 300° F. was used by Goertz (1952) to roast fresh turkey halves. Hens weighing an average of 15.8 pounds required a mean cooking time of 26 minutes per pound. Swickard et al. (1953) roasted frozen, defrosted Beltsville Small White turkeys weighing approximately four to five-and-three-fourths pounds for two and one-half to two and three-quarter hours at 325° F. Larger birds from 10 to 13 3/4 pounds required three to three-and-a-half hours at the same oven temperature. A United States Department of Agriculture bulletin (1954) suggested an oven temperature of 325° F. for roasting turkey. Frozen defrosted birds were roasted at 350° F. by Iacono et al. (1956) to an end-point of 185° F. as indicated by thermocouples located in the thigh, the drumstick, and at two positions in the breast.

A variation of internal temperature was reported by Edgar (1953) to be necessary in order to obtain a similar degree of doneness in turkeys roasted at 300° and 400° F. Turkeys wrapped

in aluminum foil and unwrapped birds required internal thigh temperatures of 82° and 85° C. at 300° F. and 85° and 88° C. at 400° F., respectively, to obtain meat of similar doneness. The turkeys weighed from 16 to 20 pounds and required an average cooking time of 310 minutes in the 300° F. oven when wrapped in aluminum foil; 191 minutes in the 300° F. oven if unwrapped; 204 minutes in the 400° F. oven when wrapped in aluminum foil; and 132 minutes in the 400° F. oven if unwrapped.

Tests for Doneness

Alexander et al. (1951) described a well done turkey as tender, juicy and easily disjointed. Several methods are used for determining when a turkey has reached the desired degree of doneness. Subjective methods of testing are relied on by the homemaker as is the cooking time in minutes per pound. Laboratory workers are more inclined to use internal temperatures and combinations of time and temperature for indications of doneness.

Internal Temperature. Internal temperatures of thigh, breast or stuffing have been used for determining degree of doneness. Cooley (1956) roasted frozen, defrosted turkey halves at 325° F. to 85° and to 90° C. in the thigh and in the pectoralis major. Those cooked to 85° C. in the thigh were the least done; those cooked to 90° C. in the thigh and to 85° C. in the breast were significantly more done than the group cooked to 85° C. in the thigh; whereas, those cooked to 90° C. in the breast were considered the most done of all. It was pointed out that the turkey halves roasted to 90° C. in the thigh and 85° C. in the breast

did not consistently reach the same degree of doneness. Those roasted to 90° C. in the breast were nearer the general concept of optimum doneness.

Castellani et al. (1953) roasted stuffed turkeys at 300° F. to an internal temperature of 165° F. (74° C.) in the center of the stuffing. This temperature killed food poisoning micro-organisms that had been introduced. Roasting time varied little for moist or dry stuffing. It was explained that the dry stuffing was mixed thoroughly with the inocula and therefore was slightly moist. Lowe (1955) suggested end-point temperatures of 70° to 85° C. in the stuffing for a well-done bird. A moist stuffing conducts heat more rapidly than a dry one; therefore, higher end-point temperatures are needed when a moist stuffing is used.

Cooking Time. Cooking time, in minutes per pound, is often recommended for obtaining a turkey that is well done. The United States Department of Agriculture bulletin (1954) gives total cooking time for different weight ranges of birds. Cook et al. (1949) adapted time and temperature to the weight of mature Bronze birds. The time increased with the weight of the bird and the oven temperature decreased for the heavier birds. The turkey halves required from two to three hours cooking time at 334° F.

Combination of Cooking Time and Temperature. A combination of cooking time and temperature also has been used as an end-point for roasting turkey. An oven temperature of 300° F. was used by Goertz (1952) to cook fresh turkey halves. The end-point used was 185° F. (85° C.) in the breast or until the birds were in the oven 26 minutes per pound, whichever was the shorter. Lewis (1955)

roasted fresh and defrosted halves at 300° F. to an internal thigh temperature of 185° F. (85° C.) or until the birds were in the oven 26 minutes per pound, whichever was the longer.

Subjective Methods. Alexander et al. (1951) cooked turkeys until tendons in the joints softened and until fleshy portions of the breast and thigh speared tender with a fork. These tests for doneness were validated by other organoleptic observations. In this study they found that subjective methods were more reliable for doneness than internal temperatures. In the satisfactorily done birds, internal thigh temperatures varied from 90° to 94° C.; internal breast temperatures varied from 80° to 95° C.; and internal stuffing temperatures varied from 80° to 94° C. Turkeys were considered done by Swickard et al. (1953) when the leg joints moved freely and the flesh on the legs felt soft to the touch. The United States Department of Agriculture (1954) suggested these same tests for doneness.

PROCEDURE

Twenty frozen Broad Breasted Bronze turkey hens of similar age, weight range (11.0 to 13.0 pounds) and past history were purchased from Armour and Company. The birds were eviscerated immediately after killing, chilled, placed in Cry-o-vac bags and kept in frozen storage until shipped to Kansas State College. In preparation for this study the birds were cut in half lengthwise along the keel bone and coded. The right and left sides were designated as such as the turkeys were placed breast side up with the anterior end facing the worker. The half birds were wrapped

in aluminum foil (.0015 gauge) and stored at -10° F. in a large walk-in freezer in the Animal Husbandry Department. Previous to the time of cooking, the birds were moved to a home-style freezer located in the Food Research Laboratory. This freezer also was maintained at -10° F.

The birds were cooked according to a randomized complete block design; a block consisted of four halves from two turkeys selected at random. Thigh temperatures of 90° and 95° C. and pectoralis major temperatures of 85° and 90° C. were used as end-points for roasting at each cooking period (Table 1).

The turkey halves were roasted in a preheated oven maintained at 325° F. Previous to cooking, the wrapped birds were defrosted at room temperature for 18 hours (Plate I). In preparation for roasting, each half (minus the neck and the giblets) was placed cut side down on a rack in an aluminum pan with a piece of aluminum foil shaped to fit the cut surface of the bird. A Centigrade thermometer was inserted in the midpoint of the pectoralis major just above the point of the keel bone. A second thermometer was inserted in the center of the thigh muscles, not too close to the bone yet still in the center of the muscles (Plates II and III). The half birds were weighed before and after cooking and volatile, dripping and total cooking losses were determined.

Internal temperatures of the pectoralis major and thigh muscles were recorded every 20 minutes; the thermometers were read through a window in the oven door. When the birds reached the specified end-point temperature in the thigh or breast as determined by the statistical design, they were removed from the oven,

Table 1. Randomized complete block design for roasting turkey halves.

Cooking Period	Sample Number							
	1		2		3		4	
1	90° C.	Breast	90° C.	Thigh	85° C.	Breast	95° C.	Thigh
2	90° C.	Breast	95° C.	Thigh	85° C.	Breast	90° C.	Thigh
3	85° C.	Breast	95° C.	Thigh	90° C.	Thigh	90° C.	Breast
4	90° C.	Breast	85° C.	Breast	95° C.	Thigh	90° C.	Thigh
5	90° C.	Breast	95° C.	Thigh	85° C.	Breast	90° C.	Thigh
6	85° C.	Breast	90° C.	Thigh	95° C.	Thigh	90° C.	Breast
7	95° C.	Thigh	90° C.	Thigh	90° C.	Breast	85° C.	Breast
8	85° C.	Breast	90° C.	Thigh	90° C.	Breast	95° C.	Thigh
9	90° C.	Thigh	90° C.	Breast	95° C.	Thigh	85° C.	Breast
10	95° C.	Thigh	90° C.	Thigh	90° C.	Breast	85° C.	Breast

EXPLANATION OF PLATE I

Defrosting of aluminum foil-wrapped frozen half turkey.

PLATE I

EXPLANATION OF PLATE II

Defrosted half turkey with thermometers inserted in the breast and in the thigh muscles.

PLATE II

EXPLANATION OF PLATE III

Roasted half turkey.

PLATE III

promptly weighed and loosely covered with aluminum foil.

Soon after the birds were removed from the oven, a trained committee of four people subjectively judged the roasted half-turkeys for degree of doneness by pricking the drumstick and the wing with a fork, by moving the knee-joint, by feeling the drumstick and by noting the general appearance of the bird as to color and dryness of the skin.

The birds were cooled approximately two hours before sampling. After this time the skin of the thigh and breast was removed and the composite thigh muscles and the pectoralis major muscle separated from the carcass. The thigh samples were numbered from the distal end of the muscle and the pectoralis major samples from the medial to the lateral side (Plates IV and V). The judges received samples of the same number and consequently from the same position of the muscles at each judging period. The juice that exuded from the birds during carving was collected and poured into coded bottles for scoring.

Two trained palatability committees of seven members each were set up for organoleptic evaluation of the samples. One group scored the light meat and the other, the dark meat. Both palatability committees scored the juice for degree of doneness.

All panels used a seven-point scale for subjective scoring. Flavor, juiciness and tenderness were scored on this scale, in which the most desirable score was seven and the most undesirable, one. Doneness of the meat and juice, and doneness tests on the whole bird soon after removal from the oven were rated on the seven-point scale with the optimum degree of doneness represented

EXPLANATION OF PLATE IV

Top. Thigh muscles.

Bottom. Thigh muscles as cut for palatability samples.

PLATE IV

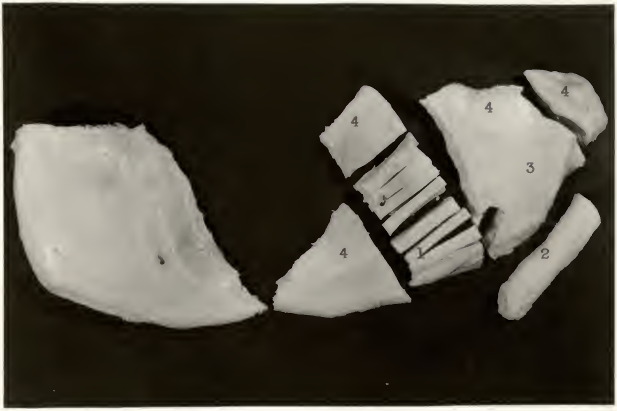
EXPLANATION OF PLATE V

Left. Pectoralis major muscle.

Right. Pectoralis major muscles used for objective and subjective tests.

1. Palatability samples.
2. Shear core.
3. Position from which core was taken.
4. Portion ground for press fluid samples.

PLATE V



by the mid-point, four. The top of the scale, seven, described the sample as very overdone, whereas the bottom of the scale, one, rated the sample as very underdone. The remainder of the scale represented intermediate degrees of doneness.

Shear values on a one-inch core from the pectoralis major were determined on a Warner-Bratzler shearing apparatus according to the method described by Hay (1952). The core was removed from the upper portion of the cooked pectoralis major muscle (Plate V). Four readings were taken and an average was used as the shear value for the core.

Press fluid determinations were made on a ground sample of the portion of the pectoralis major remaining after the shear core and palatability samples were taken (Plate V). On the day following roasting, the ground meat that had been stored in the refrigerator overnight was allowed to reach room temperature, and was then pressed on a Carver Laboratory Press according to the method described by Hay (1952). Press fluid yields were determined in duplicate, and the volume of serum, fat and total fluids was recorded.

Mean values for the data collected at each cooking period were used for all statistical analyses. Palatability factors, shear values, press fluid yields, cooking losses and cooking time were considered. The degree of doneness of light meat and of dark meat as well as that for the juice that exuded from the bird when it was carved also were included. In addition, means of all evaluations on degree of doneness made before carving the birds were analyzed.

Analyses of variance were run to determine the effect of the four variables used in the study (roasting to internal temperatures of 85° and 90° C. in the pectoralis major and 90° and 95° C. in the thigh muscles) on the factors listed in the preceding paragraph. Also included in the analyses were differences due to cooking periods. If the F values were significant, least significant differences were determined to establish the specific variable and/or variables to which the differences could be attributed.

Since light meat and dark meat samples were scored by two separate palatability committees, separate analyses were determined for each and a statistical comparison of the two was not made.

Correlation coefficients were determined in two ways. First, all data from all variables for a given factor were combined for comparison with all data for another factor. Second, two factors were compared using the data from only one variable at a time. The possibility of relationships between shear values and tenderness, press fluid yields and juiciness, press fluid yields and total cooking losses, total cooking losses and juiciness were investigated. Correlation coefficients were determined for many of the measurements for degree of doneness.

RESULTS AND DISCUSSION

Roasting turkey to a satisfactory degree of doneness presents a problem in that the numerous muscles of the bird differ widely in size and shape and also in respect to amount and distribution of the fat, connective tissue and myoglobin. These factors make it

difficult to obtain a turkey with both an optimumly cooked breast and thigh, because if the breast is roasted to optimum doneness, the thigh may be less tender and underdone; whereas, if the thigh is cooked to a satisfactory degree of doneness the breast meat may be dry and stringy.

In the present study internal temperatures of 85° and 90° C. in the breast and 90° and 95° C. in the thigh were used for roasting turkey halves. Light and dark meat were taken from the pectoralis major and thigh muscles from each bird roasted to each of the end-point temperatures. In the discussion that follows, the terms pectoralis major and breast will be used interchangeably. These two terms and thigh will be used when reference is made to the muscle in which the end-point temperature was taken. The terms light and dark refer to the samples removed from the birds irrespective of the muscle in which the end-point was recorded.

Rate of Heat Penetration

The internal temperatures of the breast and the thigh muscles began rising immediately after the turkey halves were placed in the oven. The average increase in internal temperature for these two muscles of the 40 halves is shown in Table 2. After the first 80 minutes in the oven, the means represent a decreasing number of birds for each 20-minute interval. The figures for the temperature rise beyond the 120-minute period are probably not typical because they represent a small number of halves.

During the first 20 minutes in the oven, the breast temperature of the turkeys rose more rapidly than did the thigh

Table 2. Average increase in temperature (^{o} C.) in the pectoralis major and in the thigh muscles during roasting.

	Pectoralis Major 85° C.		Thigh 90° C.		Pectoralis Major 90° C.		Thigh 95° C.		Grand Average	
Minutes	Br	Th	Br	Th	Br	Th	Br	Th	Br	Th
0 - 20	15	7	15	9	14	9	15	6	15	8
20 - 40	18	12	17	14	16	12	17	11	17	12
40 - 60	15	19	16	18	16	19	15	21	15	19
60 - 80	11	17	11	17	12	18	12	16	12	17
80 - 100	10	13	7	13	8	13	9	12	9	13
100 - 120	6*	11*	5	10	6	10	6	10	6	10
120 - 140	7**	9**	4**	8*	5*	9*	4	8	5	9
140 - 160	6*		5**	16**	3*	5*	3	5	4	7
160 - 180					1**	7**	2**	3**	2	5

**Averages of 1 to 3 figures.
*Averages of 4 to 6 figures.
Other averages contain 7 to 10 figures.

temperature. For example, the average rise in internal temperature of the birds cooked to 85° C. in the breast was 15° C. in the pectoralis major and 7° C. in the thigh during this first period. This was typical of all groups. The rate of heat penetration in the breast was rapid and similar for the first three 20-minute periods, whereas temperatures in the thigh muscle rose slowly at first and increased gradually until the most rapid increases were noted after the bird had been in the oven approximately one hour. According to Scott (1956) the light meat of roasted mature Bronze females is composed of 8.3 percent fat as compared with 12.1 percent fat in the dark meat. Interior fat in beef was shown to slow heat penetration (Thille, 1932). Small clumps of fat were found by Goertz et al. (1955) to be distributed throughout the thigh; whereas, they noted that large clumps of fat were distributed in a few scattered areas of the breast, and that the total amount of fat in the breast was less than that in the thigh. Considering the findings of these workers, the slower rate of heating in the thigh might be attributed to the difference in the amount and distribution of fat in the two muscles.

A lag in temperature rise was evident in the breast muscle after the turkey halves were in the oven 80 minutes, and was somewhat ahead of that of the thigh in which a temperature lag was not noted until after these same birds were in the oven 100 minutes. A decrease in the rate of heat penetration indicated that coagulation of the proteins with the absorption of heat was taking place. Coagulation of proteins began at approximately 60° C. in both the breast and the thigh muscles. After coagulation began,

there was a progressive decline in the rate of heat penetration of the muscles until the turkey halves were taken from the oven. An exception to this was noted in two cases. A 16° C. rise during the 140-to 160-minute period was attributed to one turkey half in the last cooking period (Table 2). A 7° C. rise, also due to a single turkey half, was noted between the 160- to 180-minute cooking period. These unusual increases in temperature might be attributed to a possible movement of the bulb of the thermometer away from the center of the muscle whereby the temperature of the outer portion of the muscle was registered instead of that for the center of the muscle.

The work of Alexander et al. (1951) reported considerably higher thigh temperatures than breast temperatures in well-done birds. In the present study such results were noted in 25 of the 40 halves roasted. In a similar study, Cooley (1956) reported that after 80 minutes in the oven only eight out of 40 halves had higher thigh than breast temperatures. Of the halves remaining in the oven up through the 120-minute period, 17 of the 33 birds had higher thigh temperatures. The results for the birds cooked 120 minutes are more comparable to those for birds that Cooley roasted for 80 minutes. The difference in the rate of heat penetration of the muscles in this study and that reported by Cooley (1956) might be attributed to differences in initial temperature of the muscles, particularly in the thigh. Although the turkeys in this study were defrosted for the same length of time, fluctuations of the room temperature may have influenced the initial temperature; mean temperatures for breast and thigh were 11° and 4° C.,

respectively, as compared with 13° C. in the breast and 9° C. in the thigh in Cooley's study. Differences in the placement of the thermometers also may have had some bearing on the observations of heat penetration. Even though the procedure for placing the thermometer in the thigh was similar for these two studies, it is possible that in the work reported here the thermometer may have been placed deeper in the muscle than it was in the work of Cooley. If so, this also may have had some effect on the explanation for differences in rate of heat penetration of the two muscles during the first hour of roasting.

Subjective and Objective Tests

Before carving, roasted turkey halves were scored for doneness by four judges. This first evaluation was made soon after the turkeys were removed from the oven. Approximately two hours later, two trained palatability committees, one for the light and the other for the dark meat, scored samples of roasted turkey halves for flavor, tenderness, juiciness and doneness of meat and juices. Cooking losses, cooking times, shear values and press fluid yields also were determined. An average of mean scores for objective and subjective evaluations are given in Table 3 and a summary of the least significant differences is given in Table 4.

Flavor. The four end-points of roasting had no significant effect on the flavor of the dark or the light meat. Average of mean scores for light meat were similar, regardless of the end-point of cooking. The dark meat of turkeys cooked to 90° C. in the pectoralis major had the highest average flavor score, but it

Table 3. Summary of analyses of variance, least significant differences, average of mean scores and objective test means for roasted turkey halves.

Factors	F	Lsd[1]	Pectoralis Major 85° C.	Thigh 90° C.	Pectoralis Major 90° C.	Thigh 95° C.
Flavor						
Light	ns		5.4	5.5	5.5	5.5
Dark	ns		5.2	5.3	5.5	5.2
Tenderness						
Light	ns		6.3	6.1	6.4	6.6
Dark	ns		5.6	5.6	5.8	5.6
Shear Values, lbs.	**	1.8	10.6	12.3	11.7	9.0
Juiciness						
Light	ns		5.0	5.3	4.8	4.8
Dark	*	0.5	5.2	5.7	5.3	5.0
Press Fluids, ml./25g.	***	0.5	9.6	9.8	8.8	9.1
Cooking Losses, %						
Total	***	3.7	19.2	19.8	25.8	25.7
Dripping	ns		6.2	5.7	7.7	7.1
Volatile	**	3.1	12.8	14.0	17.9	18.4
Cooking Time Min./lb.	***	2.7	20.7	21.8	25.7	27.1
Doneness						
Light	*	0.6	3.9	4.3	4.5	4.8
Dark	ns		4.0	4.1	4.2	4.2
Juice	ns		3.5	3.8	3.8	3.7
Fork Pr., Drumstick	*	0.8	3.8	3.9	4.8	4.8
Fork Pr., Wing	*	0.8	3.9	3.9	4.6	4.8
Feel of Drumstick	*	1.0	3.8	3.9	4.8	5.1
General Appearance	**	0.8	3.7	4.0	5.0	4.8
Movement of Joint	*	0.8	3.6	3.6	4.5	4.8

1 least significant differences at the 5% level.
ns - non-significant.
* - significant at the 5% level.
** - significant at the 1% level.
***- significant at the 0.1% level.

Table 4. Summary of least significant differences among muscle and temperature (° C.) combinations.

Factors	Pectoralis Major 85° C.			Thigh 90° C.			Pectoralis Major 90° C.			Thigh 95° C.		
	Th 90°	PM 90°	Th 95°	PM 85°	PM 90°	Th 95°	PM 85°	Th 90°	Th 95°	PM 85°	Th 90°	PM 90°
Shear Values	n*	ns	n*	n*	ns	*	ns	ns	*	n*	*	*
Juiciness, Dark	*	ns	ns	*	ns	*	ns	ns	ns	ns	*	ns
Total Press Fluids	ns	*	*	ns	*	*	*	*	ns	*	*	ns
Total Cooking Losses	ns	*	*	ns	*	*	*	*	ns	*	*	ns
Volatile Losses	ns	*	*	ns	*	*	*	*	ns	*	*	ns
Cooking Time	ns	*	*	ns	*	*	*	*	ns	*	*	ns
Doneness, Light	ns	*	*	ns	ns	n*	*	ns	ns	*	n*	ns
Fork Pricking,Drumstick	ns	*	*	ns	*	*	*	*	ns	*	*	ns
Fork Pricking, Wing	ns	n*	n*	ns	n*	n*	n*	n*	ns	n*	n*	ns
Feel of Drumstick	ns	*	*	ns	n*	*	*	n*	ns	*	*	ns
General Appearance	ns	*	*	ns	*	*	*	*	ns	*	*	ns
Movement of Joint	ns	*	*	ns	*	*	*	*	ns	*	*	ns

ns - non-significant.
n* - nearly significant at the 5% level.
* - significant at the 5% level.

was not significantly better than the dark meat from birds in the other three groups. Scores for light meat were similar or slightly higher than those for dark meat (Table 3).

Tenderness. No significant effect on the tenderness of the light or the dark meat could be attributed to the end-point temperatures used in this study. Although the difference was not significant, the light meat samples from turkeys cooked to the higher thigh temperature scored most tender, whereas those at the lower thigh temperature were least tender.

With all birds, the light meat samples were rated somewhat more tender than the dark meat samples. This agrees with the work of Cooley (1956), but disagrees with that of Marsden (1952) who found thigh meat more tender than breast meat. This may have been brought about by differences between roasting half turkeys (Cooley) and whole birds (Marsden). The rate of heat penetration in a whole bird and position of the bird during cooking may affect tendering of the muscles. The dark meat samples from turkeys roasted to 90° C. in the pectoralis major were scored slightly higher for tenderness; the turkeys cooked to the three other end-points had similar scores.

The various end-point temperatures had a highly significant effect on the shear values of the cores from the pectoralis major muscle. The cores from the breast muscle of birds roasted to 95° C. in the thigh had the lowest shear values, followed by those of the birds roasted to 85° C. in the pectoralis major, 90° C. in the pectoralis major and 90° C. in the thigh. Differences in the shear values of the birds cooked to the two end-points measured in

the breast were not significant, but shear values of the birds roasted to 95° C. in the thigh were significantly more tender than those roasted to 90° C. in the pectoralis major or to 90° C. in the thigh. The shear values did not correlate significantly with the organoleptic tenderness scores of the breast meat
(r. = -.208).

Statistical analysis showed that the cooking periods had a very highly significant effect on the shear values. This may be traced to one bird in the third cooking period that had unusually high shear values for each half. This was possibly the result of freezing the bird before rigor had completely passed.

Juiciness. The juiciness of the light meat from roasted turkey halves was not significantly affected by the variation in end-points of cooking. However, the light meat from birds roasted to the lower end-points of 85° C. in the breast and 90° C. in the thigh received higher juiciness scores than those roasted to 90° C. in the breast and to 95° C. in the thigh.

The end-point of 95° C. in the thigh did have a significant effect on the juiciness of the dark meat in that samples from these birds had significantly lower juiciness scores than samples from birds with end-points of 85° C. in the breast, 90° C. in the thigh and 90° C. in the breast. The highest juiciness scores for both the light and dark meat were given to those samples from turkeys roasted to 90° C. in the thigh. Dark meat was considered juicier than light meat. This observation agrees with that of Marsden (1952) who also found dark meat of turkey more juicy than light meat.

The end-point temperatures that were used had a very highly significant effect on the press fluid yields from the pectoralis major muscle of the roasted turkey halves. The press fluid yields from the breast of turkeys roasted to 85° C. in the pectoralis major and to 90° C. in the thigh were similar, and were significantly greater than the yields from birds cooked to 90° C. in the breast and 95° C. in the thigh. Breast muscle from birds cooked to the latter two end-points also yielded similar quantities of press fluid. Thus, press fluid yields were increased by decreasing the internal temperatures to which the birds were cooked. A highly significant but not practical correlation ($r. = +.456$) was noted between juiciness scores for the light meat and the press fluid yields.

The total cooking losses for the turkey halves were affected significantly ($P < .001$) by the end-point temperatures. Losses for the birds roasted to internal temperatures of 85° C. in the breast and 90° C. in the thigh were similar and significantly lower than the losses for turkeys cooked to the end-points of 90° C. in the pectoralis major and 95° C. in the thigh. A very highly significant correlation ($r. = -.648$) existed between juiciness scores of light meat and total cooking losses, whereas the correlation coefficient ($r. = -.397$) for juiciness scores of dark meat and total cooking losses was significant at the 1 percent level. There also was a very highly significant correlation between total cooking losses and press fluids ($r. = -.733$). Differences in dripping losses attributed to end-point temperatures were non-significant.

The effect of the several end-point temperatures on the volatile losses was highly significant; for as temperatures increased, volatile losses increased. Birds with terminal points of 90° and 95° C. in the thigh had greater volatile losses than birds with breast end-points of 85° and 90° C., respectively. The turkeys cooked to 95° C. in the thigh had greater volatile losses ($P < .05$) than those cooked to 90° C. in the thigh; turkeys roasted to 90° C. in the breast had greater volatile losses ($P < .05$) than those roasted to 85° C. in the breast; and those cooked to 90° C. in the breast had greater volatile losses ($P < .05$) than those cooked to 90° C. in the thigh.

The end-point temperatures that were used had a very highly significant effect on the total cooking time, for as the end-point temperature increased, the cooking time increased. Birds cooked to 85° C. in the breast and to 90° C. in the thigh had similar cooking times which were shorter ($P < .05$) than for birds cooked to 90° C. in the breast and 95° C. in the thigh. Cooking time, in minutes per pound, did not appear to be lengthened by low initial temperatures of the birds. This observation agrees with that of Edgar (1953) and Cooley (1956).

Doneness. The doneness of the light meat of the roasted turkeys was significantly affected by changing the end-point temperatures. Light meat from birds cooked to an internal temperature of 95° C. in the thigh was considered most done, whereas samples from turkeys cooked to 90° C. in the pectoralis major, 90° C. in the thigh and 85° C. in the pectoralis major were increasingly less done. Using a seven-point scale with four

representing optimum doneness, the committee members scored the light meat from turkeys cooked to 85° C. in the pectoralis major between slightly underdone and done; whereas, the other three end-points produced samples that were considered between done and slightly overdone. During sampling of the 40 halves, only seven birds ever reached an average score of five or over for doneness of the light meat. This indicated that none of the end-points used in this study produced frequent cases of overdoneness. The difference in the doneness of the light meat of birds roasted to 85° C. in the pectoralis major and those roasted to 90° C. in the thigh was not significant. This also was true for the birds roasted to 90° C. in the breast and 95° C. in the thigh. Light meat samples from turkeys roasted to 90° C. in the pectoralis major and 95° C. in the thigh were significantly more done than the birds with end-points of 85° C. in the pectoralis major.

The degree of doneness of dark meat was not significantly affected by differences in the end-point temperatures used in this study. Three out of 40 roasted half turkeys received average dark meat doneness scores over five, indicating that overdone dark meat would seldom be a problem when similar internal temperatures are used as end-points for cooking. The scores for the dark meat indicated that it was slightly less done than the light meat, but still considered within the range of doneness.

When the exuded juice from turkeys cooked to varying internal temperatures was used as the criteria for judging degree of doneness, significant differences were not observed. This disagrees with Cooley (1956) who found that degree of doneness could be

judged easily by observation of the juice which exuded on carving. Comments of the panel members during this study indicated that they experienced difficulty in scoring the juices as there was considerable variation in quantity and color of the juice at different scoring periods. Average scores for doneness of the juice were similar for all birds, and all were scored as slightly underdone.

When the degree of doneness was evaluated by pricking the drumstick and the wing with a fork, significant differences were noted in the judges' scores of turkeys roasted to different internal temperatures. The birds cooked to 90° C. in the pectoralis major and 95° C. in the thigh were determined to be equally done and significantly more done than those roasted to 85° C. in the pectoralis major and to 90° C. in the thigh which were similar to each other, but less done than birds in the other two groups. Scores were so similar for drumstick and wing that it is believed that the judges probably subconsciously were influenced in their scores for the wing after rating the drumstick for degree of doneness.

The feel of the drumstick was significantly affected by the four end-point temperatures. When using this criteria for evaluating doneness, the committee scored the turkey halves roasted to 90° C. in the breast and to 95° C. in the thigh as slightly underdone. Statistically, the difference between scores for birds roasted to 95° C. in the thigh and 90° C. in the breast was not significant, nor was the difference between scores for birds with end-points of 90° C. in the thigh and 85° C. in the breast. The

feel of the drumstick showed the birds roasted to temperatures of 90° C. in the breast and 95° C. in the thigh to be significantly more done than those roasted to 85° C. in the breast and 90° C. in the thigh.

Doneness, as determined by the scoring committee's appraisal of the general appearance and ease of moving the knee-joint, resulted in significant differences that could be attributed to varying the end-point temperatures. Again, the turkeys roasted to 85° C. in the breast and to 90° C. in the thigh were not significantly different when judged by these criteria, and were slightly underdone with the exception of the birds cooked to end-points of 90° C. in the thigh; these were given an average score of four for general appearance. No significant differences in appearance or ease of moving the knee-joint were noted in birds roasted to a pectoralis major temperature of 90° C. and those cooked to a thigh temperature of 95° C. Averages of mean scores were slightly above the optimum, four, for appearance and movement of the knee-joint, but only the general appearance of the birds roasted to a pectoralis major temperature of 90° C. had a mean score of five, slightly overdone.

The subjective scoring of the roasted birds by the household methods of pricking with a fork, noting general appearance, feeling the drumstick, and moving the knee-joint all had very highly significant correlations with the palatability committee's judgment of doneness of light and dark meat (Table 5).

In general, most methods used for evaluating degree of doneness indicated that turkeys roasted to 90° C. in the pectoralis

Table 5. Correlation coefficients (r values) of subjective tests for doneness.

Correlation Factors	Combination of Four Variables	Pectoralis Major 85° C.	Thigh 90° C.	Pectoralis Major 90° C.	Thigh 95° C.
Movement of Joint vs. Doneness of Dark Meat	.589***	.674*	.553ns	.389ns	.818**
Fork Pricking of Drumstick vs. Doneness of Dark Meat	.490***	.954***	.507ns	.184ns	.634*
Feel of Drumstick vs. Doneness of Dark Meat	.576***	.949***	.500ns	.172ns	.647*
Fork Pricking of Wing vs. Doneness of Light Meat	.522***	.685*	.456ns	-.112ns	.299ns
General Appearance vs. Doneness of Light Meat	.492***	.242ns	.771**	-.229ns	.236ns
General Appearance vs. Doneness of Dark Meat	.560***	.697*	.591ns	.486ns	.605ns
General Appearance vs. Doneness of Juice	-.045ns	-.232ns	-.106ns	-.238ns	.346ns
Doneness of Juice vs. Doneness of Light Meat	.069ns	-.228ns	.076ns	.012ns	.223ns
Doneness of Juice vs. Doneness of Dark Meat	-.055ns	-.456ns	.097ns	.097ns	-.012ns

ns - non-significant.
* - significant at the 5% level.
** - significant at the 1% level.
***- significant at the 0.1% level.

major and 95° C. in the thigh were more done than those roasted to end-points of 85° C. in the breast and 90° C. in the thigh. This was true in all cases except when doneness of dark meat and exuded juice were judged, and then no significant differences were noted. Light meat from birds cooked to 90° C. in the pectoralis major and 95° C. in the thigh was considered equally done, and significantly more done than that from birds roasted to 85° C. in the pectoralis major and 90° C. in the thigh. These samples were similar to each other, but less done than those from the other two groups. When the household methods were used in judging degree of doneness before the birds were carved, on the whole, similar results were obtained as discussed for doneness of light meat.

It seemed that it was easier to place the thermometer in a similar location in the breast muscle from time to time than it was to do so in the thigh. It is therefore recommended that an end-point of 90° C. in the pectoralis major muscle be used for roasting turkey halves to an optimum degree of doneness.

SUMMARY

Forty frozen Broad Breasted Bronze turkey halves were defrosted at room temperature and roasted in a rotary hearth oven maintained at 325° F. to end-point temperatures of 85° and 90° C. in the breast and 90° and 95° C. in the thigh.

Internal temperatures of the breast and thigh muscles were recorded every 20 minutes during roasting. Breast temperatures of all birds increased rapidly and at a similar rate during the first

hour of roasting; whereas thigh temperatures rose slowly during the first 20 minutes, and then increased progressively until the rate of heat penetration became similar for the two muscles. Since the temperature rose more rapidly in the breast than in the thigh, coagulation of protein began in the breast muscle after a shorter time interval than was noted for the thigh. After coagulation of proteins started, the rate of heat penetration was progressively slower until the birds were taken from the oven.

Doneness of half turkeys was judged soon after they were removed from the oven and before the birds were carved. Later, two palatability committees, one for the light and the other for the dark meat, scored samples of roasted turkey halves for flavor, tenderness, juiciness and doneness of the meat and juice. Cooking losses, cooking times, shear values and press fluid yields also were determined.

Turkey halves that were cooked to end-points of 85° C. in the breast and 90° C. in the thigh were scored similarly for doneness of the light meat, the dark meat and the juice, but were considered less done than were birds roasted to end-points of 90° C. in the breast and 95° C. in the thigh. These latter two groups also were scored similarly for degree of doneness. Scores for dark meat and for the exuded juice from the birds at all end-point temperatures were not significantly different. However, the light meat samples from birds roasted to the two higher end-points, 90° C. in the breast and 95° C. in the thigh, were scored as more done ($P < .05$) than those in the group roasted to 85° C. in the breast. The light meat samples from the birds roasted to

90° C. in the thigh were considered less done than that from birds cooked to 90° C. in the breast and to 95° C. in the thigh, although the difference was not significant. On the whole, scores for the household methods of determining doneness (general appearance, fork pricking of the wing and drumstick, feel of the drumstick and movement of the joint) indicated that significant differences existed between the turkeys roasted to the lower end-points and those roasted to the two higher end-points. Again, a greater degree of doneness was noted for the birds roasted to the two higher temperatures, 90° C. in the breast and 95° C. in the thigh.

Although there were differences in the degree of doneness produced by the end-point temperatures, several of the palatability factors were not affected. There was no relationship between flavor and doneness as flavor of the light and dark meat samples was not significantly changed by varying the end-point temperatures. Scores for tenderness of the light and dark meat were similar for all birds, regardless of the degree of doneness. Shear values of the pectoralis major did not correlate with tenderness scores for light meat. Varying the end-point temperature did not affect the juiciness of the light meat; however, significant differences were found in the juiciness scores for the dark meat. The birds roasted to 90° C. in the thigh were the most juicy and those cooked to 95° C. in the thigh, the least juicy. Press fluid yields were lower when the birds were considered most done and higher for those that were least done.

Varying the end-point temperature and therefore the degree of doneness significantly increased the volatile ($P < .01$) and

total cooking losses ($P < .001$). The birds roasted to the two higher end-points, 90° C. in the breast and 95° C. in the thigh, were rated more done and had approximately five percent greater cooking losses than did the birds cooked to the two lower end-point temperatures, 85° C. in the breast and 90° C. in the thigh. Dripping losses were similar for birds in all groups. The total cooking time required for the birds at the higher end-point temperatures was about five minutes per pound longer than for the birds at the lower end-point temperatures. The difference was significant at the 0.1 percent level.

Generally, the turkey halves roasted to end-point temperatures of 85° C. in the breast and 90° C. in the thigh were similar and less done than those roasted to 90° C. in the breast and 95° C. in the thigh. The birds in the latter two groups also were similar. Either of the higher end-point temperatures could be used to produce satisfactorily done birds. It is suggested, however, that it is easier to place the thermometer in a similar position in the breast from time to time than it is to do so in the thigh. Therefore, it is recommended that an end-point temperature of 90° C. in the pectoralis major muscle be used for roasting turkey halves to an optimum degree of doneness.

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APPENDIX

Form 1. Weight losses of roasted turkey halves before and after cooking.

I. Losses by weight — Grams

A. Before cooking

1. Weight of bird.

2. Weight of pan, rack, foil and thermometer.

3. Weight of pan, rack, foil, thermometer and bird.

B. After cooking

1. Weight of pan, rack, foil, thermometer and drippings.

2. Volatile loss (A3 - B1).

3. Weight of bird and platter.

4. Weight of platter.

5. Cooked weight of bird (B3 - B4).

6. Total cooking loss (A3 - B5).

7. Dripping loss (B7 - A3).

II. Losses as percent of weight — Percent

A. Volatile loss (B2 + A1).

B. Total cooking loss (B6 + A1).

C. Dripping loss (B8 + A1).

Form 2. Score card for turkey.

Name ____________________ Date ____________

Sample	Fork Pricking		Feel of Drumstick	General Appearance	Movement of Joint
	Drumstick	Wing			
1.					
2.					
3.					
4.					

1-very underdone
2-mod. underdone
3-sl. underdone
4-done
5-sl. overdone
6-mod. overdone
7-very overdone

Form 3. Score card for turkey.

NAME____________________ DATE____________________

EATING QUALITY

Sample	Flavor	Juiciness	Tenderness
1.			
2.			
3.			
4.			

Descriptive Terms for Flavor, Juiciness, and Tenderness:

7-very desirable
6-desirable
5-mod. desirable
4-sl. desirable
3-sl. undesirable
2-mod. undesirable
1-undesirable

DONENESS

Meat	Juice*

Descriptive Terms for Doneness of Meat and Juice:

7-very overdone
6-mod. overdone
5-sl. overdone
4-done
3-sl. underdone
2-mod. underdone
1-very underdone

*The number of the juice sample is not necessarily the same as the meat sample.

TEXTURE

Place the sample number by the word which best describes its texture:

Very fine________
Fine________
Mod. fine________
Mod. coarse________
Coarse________
Very coarse________
Stringy________
Powdery________
Dry________
Fiber separation________

Comments:

Table 6. Randomization for meat and juice samples for roasted turkey halves.

Cooking Period	Code No. of Bird	Variable	Meat Sample No.	Juice Sample No.
1	XII A	90° C. Breast	1	2
	III A	90° C. Thigh	2	3
	III B	85° C. Breast	3	1
	XII B	95° C. Thigh	4	4
2	XV A	90° C. Breast	1	2
	XV B	95° C. Thigh	2	3
	XX B	85° C. Breast	3	4
	XX A	90° C. Thigh	4	1
3	IX B	85° C. Breast	1	3
	IX A	95° C. Thigh	2	4
	IV B	90° C. Thigh	3	2
	IV A	90° C. Breast	4	1
4	XI B	90° C. Breast	1	4
	VIII B	85° C. Breast	2	2
	VIII A	95° C. Thigh	3	1
	XI A	90° C. Thigh	4	3
5	XIII A	90° C. Breast	1	1
	I B	95° C. Thigh	2	2
	I A	85° C. Breast	3	4
	XIII B	90° C. Thigh	4	3
6	XVIII A	85° C. Breast	1	1
	XVIII B	90° C. Thigh	2	3
	VI B	95° C. Thigh	3	2
	VI A	90° C. Breast	4	4
7	XIX B	95° C. Thigh	1	4
	V B	90° C. Thigh	2	2
	V A	90° C. Breast	3	3
	XIX A	85° C. Breast	4	1
8	VII B	85° C. Breast	1	4
	XVI B	90° C. Thigh	2	3
	XVI A	90° C. Breast	3	2
	VII A	95° C. Thigh	4	1
9	XIV B	90° C. Thigh	1	3
	XIV A	90° C. Breast	2	1
	II B	95° C. Thigh	3	4
	II A	85° C. Breast	4	2
10	X A	95° C. Thigh	1	2
	XVII A	90° C. Thigh	2	4
	X B	90° C. Breast	3	1
	XVII B	85° C. Breast	4	3

Table 7. Internal temperature (^{o} C.) recorded every 20 minutes in turkey halves roasted to 85^{o} C. in the pectoralis major muscle.

Minutes										
0	20	40	60	80	100	120	140	160	180	Total
Pectoralis Major										
8	18	35	50	62	73	80				137
13	40	55	60	76	80	83				133
17	28	44	60	70	80					116
5	15	28	43	58	69	79				138
7	17	35	55	61	72	78	83	89		155
8	23	38	54	65	72	76	84			143
13	26	43	58	69	77	83				132
12	34	55	69	78	84					105
14	32	55	72	82						88
21	36	56	71	81						96
Av. 12	27	44	59	70	76	80	84	89		124
Thigh										
2	8	25	55	65	78	86				
3	11	16	34	56	67	77				
13	20	35	57	71	84					
1	4	13	30	48	63	75				
-1	9	26	48	66	78	86	95	94		
0	9	15	34	53	65	78	87			
5	13	28	45	61	73	85				
-1	1	11	20	40	59					
4	10	24	45	62						
18	33	49	67	82						
Av. 4	12	24	44	60	71	81	91	94		

Table 8. Internal temperature (^{o} C.) recorded every 20 minutes in turkey halves roasted to 90^{o} C. in the thigh muscle.

Minutes										
0	20	40	60	80	100	120	140	160	180	Total
Pectoralis Major										
13	27	45	62	72	78	81				
15	27	39	50	61	71					
14	30	49	66	76	81	84				
8	23	40	56	68	77	84	89			
11	35	58	73	83	85					
15	30	47	63	75	81	86				
10	25	40	56	68	77					
11	22	37	52	64	74	80	83	88		
14	25	43	60	73	82	87				
16	35	55	70	80	86	91				
Av. 13	28	45	61	72	79	85	86	88		
Thigh										
4	12	28	50	69	80	86				135
9	27	40	56	73	86					111
5	9	25	44	64	78	85				131
0	4	16	33	52	66	78	85			152
2	9	25	43	62	83					117
9	20	33	50	66	74	85				137
2	15	40	60	72	83					116
-2	5	14	26	44	61	75	84	100		157
8	18	32	53	66	78	87				127
10	15	25	42	60	73	84				137
Av. 5	13	28	46	63	76	83	85	100		132

Table 9. Internal temperature (^{o} C.) recorded every 20 minutes in turkey halves roasted to 90^{o} C. in the pectoralis major muscle.

	Minutes									
0	20	40	60	80	100	120	140	160	180	Total
Pectoralis Major										
10	23	35	51	63	73	78	84	88		163
21	39	55	70	81	85	87				140
15	25	38	54	66	74	80	84			173
9	26	43	63	75	81	87				132
8	15	31	48	64	75	83				140
9	26	40	49	62	73	80	84	87	88	194
6	22	36	51	64	71	77	83	86		175
8	20	38	52	63	75	79	83	85		192
12	27	49	66	75	81	87				132
14	27	42	58	71	80	87				134
Av. 11	25	41	56	68	77	83	84	87	88	158
Thigh										
3	15	30	50	68	77	87	92	96		
20	28	40	57	69	78	84				
0	9	24	48	66	78	87	94			
0	12	27	48	63	74	86				
7	15	34	51	71	84	90				
4	12	22	42	61	70	82	93	97	101	
-1	7	11	20	35	55	67	81	88		
-1	4	13	30	49	68	81	91	96		
-2	9	26	51	74	89	95				
10	15	22	43	61	75	84				
Av. 4	13	25	44	62	75	84	90	94	101	

Table 10. Internal temperature (° C.) recorded every 20 minutes in turkey halves roasted to 95° C. in the thigh muscle.

	Minutes										
	0	20	40	60	80	100	120	140	160	180	Total
Pectoralis Major											
	10	29	49	64	75	82	87	88			
	14	30	42	57	63	72	78	85	93		
	7	17	32	50	63	74	81	87	87		
	10	22	37	56	70	79	86	89	92		
	6	23	43	58	69	78	82	86			
	8	25	41	57	70	75	81	83	87		
	5	17	34	50	63	73	81	84	86	88	
	9	30	49	67	80	89	91	93	95		
	15	24	41	57	71	81	86	92	96		
	14	28	45	60	75	83	88				
Av.	10	25	41	58	70	79	84	87	91	88	
Thigh											
	3	13	30	55	68	80	90	95			140
	9	17	26	39	58	68	79	87	90		167
	-1	3	17	42	64	78	87	93	97		144
	5	10	20	40	56	67	78	85	93		162
	4	9	22	40	60	75	83	88			166
	-1	5	15	34	55	60	70	82	88		175
	-1	8	15	42	46	60	74	83	90	93	184
	-1	1	11	22	38	57	72	84	90		173
	12	15	15	45	61	73	82	89	93		164
	8	15	32	56	73	85	92				128
Av.	4	10	20	42	58	70	81	87	92	93	160

Table 11. Average of mean flavor scores for roasted turkey halves.

Pectoralis Major		Thigh		Pectoralis Major		Thigh	
85° C.		90° C.		90° C.		95° C.	
Light	Dark	Light	Dark	Light	Dark	Light	Dark
5.0	5.4	5.1	6.0	5.4	5.7	5.6	5.1
5.8	5.4	6.0	5.6	5.4	5.6	6.0	5.1
5.5	4.7	5.5	4.8	5.4	5.7	5.4	4.3
5.9	5.7	6.1	6.3	5.3	5.8	5.0	5.7
4.9	5.7	5.1	5.0	5.3	5.0	5.3	5.5
5.8	5.0	4.6	4.4	5.0	6.0	5.6	5.2
5.4	5.3	5.8	5.7	5.6	5.1	5.0	5.6
4.6	5.0	5.2	4.7	5.6	4.9	5.6	5.0
5.0	4.5	6.0	5.5	6.4	6.0	5.2	5.2
6.0	5.1	6.0	5.4	6.0	5.4	6.0	5.6
Av. 5.4	5.2	5.5	5.3	5.5	5.5	5.5	5.2

Maximum score, seven.

Table 12. Average of mean tenderness scores for roasted turkey halves and average of mean shear values for pectoralis major muscle.

Pectoralis Major			Thigh			Pectoralis Major			Thigh		
85° C.			90° C.			90° C.			95° C.		
Light	Dark	Shear	Light	Dark	Shear	Light	Dark	Shear	Light	Dark	Shear
6.3	5.7	9.9	5.6	5.7	11.5	5.6	5.7	13.1	6.6	5.3	9.1
6.4	5.7	9.7	6.4	5.4	11.9	6.8	6.0	12.4	6.6	5.6	8.4
6.8	5.7	14.2	5.8	5.7	23.1	6.3	5.5	22.1	6.8	5.2	13.4
6.4	5.8	14.2	6.3	6.2	12.1	6.4	6.2	11.7	6.4	6.2	11.8
6.3	6.0	8.6	5.0	5.7	9.0	5.4	6.2	12.2	6.1	5.7	7.3
6.8	6.0	9.8	6.4	5.2	13.1	6.6	6.0	10.9	6.4	5.6	10.4
6.4	6.1	9.2	6.6	5.6	9.6	6.2	5.6	8.2	6.6	5.9	7.6
5.0	5.1	10.9	5.8	6.1	10.4	7.0	6.0	8.2	6.6	5.3	9.3
5.2	4.0	11.4	6.4	5.3	11.6	6.6	6.0	7.2	6.6	5.7	5.4
7.0	5.6	7.6	6.3	5.3	10.8	7.0	5.0	10.6	6.8	5.9	7.7
Av.6.3	5.6	10.6	6.1	5.6	12.3	6.4	5.8	11.7	6.6	5.6	9.0

Maximum score, seven.

Table 13. Average of mean juiciness scores for roasted turkey halves and average of mean press fluid yields for pectoralis major muscle.

	Pectoralis Major			Thigh			Pectoralis Major			Thigh		
	85° C.			90° C.			90° C.			95° C.		
	Light	Dark	P.F.[1]	Light	Dark	P.F.	Light	Dark	P.F.	Light	Dark	P.F.
	4.4	5.3	9.7	5.1	5.9	10.4	4.6	5.9	8.8	4.9	6.0	9.1
	5.2	4.9	9.1	6.2	5.6	10.2	5.0	5.4	9.1	4.8	4.7	9.0
	5.3	5.0	9.2	4.8	5.3	9.9	5.5	6.0	9.0	6.3	5.3	10.7
	5.4	5.5	9.3	5.3	6.0	9.7	4.6	5.7	8.7	4.7	4.5	9.4
	4.3	4.5	10.0	5.3	5.7	10.0	5.0	5.2	9.3	4.3	5.2	9.6
	5.6	4.8	9.7	4.4	5.4	9.3	5.0	4.2	7.7	5.0	5.4	8.7
	3.9	4.4	9.0	6.8	5.3	9.9	4.8	5.1	9.1	4.6	4.0	8.0
	5.4	6.0	9.6	4.8	7.0	9.6	3.6	4.4	8.1	3.8	5.4	8.7
	4.5	5.5	10.9	5.6	5.7	9.5	4.8	5.5	9.3	3.6	4.0	8.4
	5.5	5.7	9.9	5.0	5.1	9.7	5.3	5.1	9.0	5.8	5.7	9.5
Av.	5.0	5.2	9.6	5.3	5.7	9.8	4.8	5.3	8.8	4.8	5.0	9.1

[1] Press fluids.

Maximum score, seven.

Table 14. Average of mean doneness scores for meat and juice samples of roasted turkey halves.

	Pectoralis Major			Thigh			Pectoralis Major			Thigh		
	85° C.			90° C.			90° C.			95° C.		
	Light	Dark	Juice	Light	Dark	Juice	Light	Dark	Juice	Light	Dark	Juice
	4.3	4.6	2.6	4.0	3.9	3.6	4.6	3.7	4.2	4.1	3.9	3.6
	3.8	4.0	3.4	3.5	3.4	3.3	4.0	4.4	4.3	4.3	4.4	2.8
	3.8	4.7	3.2	4.5	4.2	4.7	3.8	3.3	3.1	3.8	3.2	3.1
	4.1	4.0	3.5	4.1	4.2	4.5	4.6	3.8	3.5	7.0	4.5	3.3
	4.7	4.8	3.5	4.4	3.7	2.5	4.6	3.7	4.3	5.4	4.5	4.2
	3.9	4.0	2.2	5.0	3.8	5.2	4.6	5.2	4.2	4.6	3.4	3.9
	4.2	4.3	4.7	3.2	3.6	3.5	4.4	4.1	4.4	4.4	4.6	2.1
	2.6	2.9	3.8	4.8	4.9	2.8	5.2	5.1	4.1	5.0	3.9	5.2
	2.8	2.7	4.5	4.0	4.7	4.8	4.8	4.5	2.2	5.2	5.2	4.5
	4.5	3.9	4.0	5.0	4.4	3.1	4.8	3.9	4.0	4.0	4.0	4.0
Av.	3.9	4.0	3.5	4.3	4.1	3.8	4.5	4.2	3.8	4.8	4.2	3.7

Maximum score, seven.
Optimum doneness, four.
Very overdone, seven.
Very underdone, one.

Table 15. Average of mean scores for doneness (fork pricking of the drumstick and the wing of roasted turkey halves.

	Pectoralis Major		Thigh		Pectoralis Major		Thigh	
	85° C.		90° C.		90° C.		95° C.	
	Drumstick	Wing	Drumstick	Wing	Drumstick	Wing	Drumstick	Wing
	4.7	4.7	4.0	4.0	5.7	5.7	3.3	3.3
	4.0	4.7	3.0	3.0	5.0	4.3	5.7	5.7
	5.0	4.7	5.0	4.3	6.0	5.7	4.7	5.0
	4.3	4.7	4.3	4.3	3.3	3.3	6.0	5.7
	4.8	4.8	4.5	4.5	4.5	4.8	4.5	4.5
	3.0	3.3	3.7	3.3	5.0	5.0	3.7	4.0
	3.5	3.3	3.3	3.3	4.5	4.3	4.5	4.3
	2.8	2.5	4.0	4.0	5.0	5.0	4.8	4.8
	2.0	2.3	3.3	4.0	5.0	4.7	6.0	5.7
	3.5	3.5	4.3	4.3	4.0	3.5	4.8	4.5
Av.	3.8	3.9	3.9	3.9	4.8	4.6	4.8	4.8

Maximum score, seven.
Optimum doneness, four.
Very overdone, seven.
Very underdone, one.

Table 16. Average of mean scores for doneness (feel of the drumstick, general appearance and movement of the joint) of roasted turkey halves.

	Pectoralis Major			Thigh			Pectoralis Major			Thigh		
	85° C.			90° C.			90° C.			95° C.		
	D[1]	A[2]	J[3]	D	A	J	D	A	J	D	A	J
	4.7	4.0	3.3	3.3	3.3	3.3	6.3	4.7	4.3	3.3	4.3	3.7
	4.0	4.3	4.0	3.0	3.3	2.3	4.7	5.3	3.3	6.3	5.3	5.0
	4.7	4.7	4.7	4.3	4.7	4.7	5.7	5.7	5.7	4.7	5.3	4.0
	4.7	3.3	3.3	5.0	3.7	4.7	3.3	4.3	3.0	6.3	5.3	5.7
	5.3	4.5	4.3	4.0	4.3	3.5	4.5	4.5	4.5	5.0	4.5	5.0
	3.3	3.0	3.3	4.0	4.0	3.3	5.7	5.7	6.0	4.3	3.3	4.0
	4.0	4.3	4.3	3.3	3.5	3.3	3.8	3.8	4.3	4.5	4.3	4.5
	2.0	4.0	2.8	4.5	4.5	4.0	5.3	5.8	5.3	5.0	4.3	4.8
	1.7	1.7	1.7	3.3	4.0	3.3	5.0	5.3	5.0	6.7	7.0	6.3
	4.0	3.3	3.8	4.5	5.0	4.0	4.0	4.5	3.5	4.8	4.0	4.8
Av.	3.8	3.7	3.6	3.9	4.0	3.6	4.8	5.0	4.5	5.1	4.8	4.8

[1] Feel of the drumstick.
[2] General appearance.
[3] Movement of the joint.

Maximum score, seven.
Optimum doneness, four.
Very overdone, seven.
Very underdone, one.

Table 17. Average cooking losses (percent) for roasted turkey halves.

	Pectoralis Major			Thigh			Pectoralis Major			Thigh		
	85° C.			90° C.			90° C.			95° C.		
	V[1]	D[2]	T[3]	V	D	T	V	D	T	V	D	T
	14.1	6.6	20.9	13.0	4.8	18.2	16.7	6.1	22.8	16.7	7.5	24.5
	11.5	8.4	20.2	7.9	4.4	12.7	17.2	5.7	23.2	16.6	7.9	24.6
	11.7	5.7	17.6	14.5	4.8	19.3	22.4	5.8	28.6	12.9	4.6	17.6
	14.2	4.6	19.0	15.7	7.7	23.5	13.6	8.8	22.7	19.1	7.7	26.9
	17.8	5.0	23.0	12.1	7.9	20.1	14.1	8.1	22.4	21.2	4.6	25.7
	12.8	9.3	22.3	17.2	5.7	23.1	22.5	5.3	28.0	18.2	6.1	24.6
	14.9	8.6	23.6	9.7	5.6	15.5	17.2	11.6	28.9	19.3	8.3	27.7
	9.3	4.4	14.4	18.3	4.8	23.2	25.3	9.2	34.5	23.6	9.2	32.9
	8.5	4.4	13.1	14.4	3.9	18.5	14.9	10.3	25.6	21.3	9.2	30.6
	13.0	4.6	17.7	16.7	7.2	24.3	15.4	6.0	21.4	15.4	6.3	21.8
Av.	12.8	6.2	19.2	14.0	5.7	19.8	17.9	7.7	25.8	18.4	7.1	25.7

[1] Volatile losses.
[2] Dripping losses.
[3] Total losses.

Table 18. Average cooking times for roasted turkey halves.

	Pectoralis Major	Thigh	Pectoralis Major	Thigh
	85° C.	90° C.	90° C.	95° C.
	Min./lb.	Min./lb.	Min./lb.	Min./lb.
	24.5	23.3	27.6	25.0
	20.5	16.1	25.5	25.7
	19.3	23.0	26.2	22.2
	22.6	22.0	19.4	28.5
	23.8	20.5	22.6	27.7
	21.3	24.9	27.7	30.2
	22.8	20.4	25.7	32.3
	17.8	25.7	30.5	30.4
	14.4	20.2	21.0	28.3
	19.6	21.4	20.6	21.0
Av.	20.7	21.8	25.7	27.1

Table 19. Mean squares for muscle-temperature combinations for flavor, juiciness and press fluids.

Sources of Variation	D/F	Flavor		Juiciness		Press
		Light	Dark	Light	Dark	Fluids
Muscle-Temperature Combination	3	.051	.226	.628	.950*	2.180***
Cooking Period	9	.297	.351	.491	.437	.376
Error	27	.165	.167	.441	.307	.294
Total	39					

* - significant at the 5% level.
*** - significant at the 0.1% level.

Table 20. Mean squares for muscle-temperature combinations for tenderness, shear values and doneness.

Sources of Variation	D/F	Tenderness		Shear Values	Doneness		
		Light	Dark		Light	Dark	Juice
Muscle-Temperature Combination	3	.429	.118	20.49**	1.537	.07C	.176
Cooking Period	9	.390	.225	31.97***	0.484	.054	.151
Error	27	.209	.169	3.89	0.466	.476	.867
Total	39						

** - significant at the 1% level.
*** - significant at the 0.1% level.

Table 21. Mean squares for muscle-temperature combinations for doneness by fork pricking of the drumstick and wing, feel of the drumstick, general appearance and movement of the joint.

Sources of Variation	D/F	Doneness: Fork Pricking: Drumstick	Doneness: Fork Pricking: Wing	Doneness: Feel of Drumstick	Doneness: General Appearance	Doneness: Movement of Joint
Muscle-Temperature Combination	3	3.062*	2.242*	4.011*	3.504**	3.759*
Cooking Period	9	.585	.524	.369	.499	.417
Error	27	.725	.668	1.165	.726	.851
Total	39					

* - significant at the 5% level.
** - significant at the 1% level.

Table 22. Mean squares for muscle-temperature combinations for cooking losses (total, dripping and volatile) and average cooking time.

Sources of Variation	D/F	Cooking Losses			Average Cooking Time
		Total	Dripping	Volatile	
Muscle-Temperature Combination	3	130.5***	8.338	79.98**	85.62***
Cooking Period	9	13.88	2.941	10.45	16.29
Error	27	16.21	3.540	11.45	8.93
Total	39				

** - significant at the 1% level.
*** - significant at the 0.1% level.

THE RELATIONSHIP BETWEEN DEGREE OF DONENESS
AND END-POINT TEMPERATURES OF ROASTED TURKEY HALVES

by

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It is difficult to roast turkey consistently to a satisfactory degree of doneness in that the numerous muscles of the bird differ widely in size and shape and also in respect to amount and distribution of the fat, connective tissue and myoglobin. Recommendations are needed for an objective means of determining the end-point of cooking that regularly will produce a roasted turkey with all muscles at an optimum degree of doneness.

Forty frozen Broad Breasted Bronze turkey halves were defrosted at room temperature and roasted in a rotary hearth oven maintained at 325° F. to the end-point temperatures of 85° and 90° C. in the breast and 90° and 95° C. in the thigh. Internal temperatures of the breast and thigh muscles were recorded every 20 minutes during roasting. Breast temperatures of all birds increased rapidly and at a similar rate during the first hour of roasting; whereas, thigh temperatures rose slowly during the first 20 minutes, and then increased progressively until the rate of heat penetration became similar for the two muscles. Coagulation of protein began in the breast muscle after a shorter time interval than was noted for the thigh. After coagulation of proteins started, the rate of heat penetration was progressively slower until the birds were taken from the oven.

Doneness of half turkeys was judged soon after they were removed from the oven and before the birds were carved. Later, two palatability committees, one for the light and the other for the dark meat, scored samples of roasted turkey halves for flavor, tenderness, juiciness and doneness of the meat and juice. Cooking losses, cooking times, shear values and press fluid yields also

were determined.

Turkey halves that were cooked to end-points of 90° C. in the breast and 95° C. in the thigh were scored similarly for doneness of the light meat, the dark meat and the juice, and were considered more done than the birds roasted to end-points of 85° C. in the breast and 90° C. in the thigh. On the whole, scores from the household methods for determining doneness (general appearance, fork pricking of the wing and drumstick, feel of the drumstick and movement of the joint) indicated that significant differences ($P < .05$) existed between the turkeys roasted to the higher end-point temperatures and those roasted to the lower end-point temperatures.

Although the end-point temperatures produced differences in the degree of doneness of the turkey halves, several of the palatability factors were not affected. There was no relationship between flavor and doneness as flavor of the light and dark meat samples was not significantly changed by varying the end-point temperatures. Scores for tenderness of the light and dark meat were similar for all birds, regardless of the degree of doneness. Shear values of the pectoralis major were not correlated with tenderness scores for light meat. Varying the end-point temperature did not affect the juiciness of the light meat; however, significant differences were found in the juiciness scores for the dark meat. The birds roasted to 90° C. in the thigh were the most juicy and those cooked to 95° C. in the thigh, the least juicy. Press fluid yields were lowest when the birds were considered most done and highest for those that were least done.

Varying the end-point temperature and therefore the degree of doneness significantly increased the volatile ($P < .01$) and total cooking losses ($P < .001$). The birds roasted to the two higher end-points, 90° C. in the breast and 95° C. in the thigh, were rated more done and had approximately five percent greater cooking losses than the birds from the two lower end-point temperatures, 85° C. in the breast and 90° C. in the thigh. Dripping losses were similar for birds in all groups. The total cooking time required for the birds to reach the higher end-point temperatures was about five minutes per pound longer than that for the birds cooked to the lower end-point temperatures. The difference was significant at the 0.1 percent level.

Generally, the turkey halves roasted to end-point temperatures of 85° C. in the breast and 90° C. in the thigh were similar and less done than those roasted to 90° C. in the breast and 95° C. in the thigh. The birds in the latter two groups also were similar. Either of the higher end-point temperatures could be used to produce satisfactorily done birds. It is suggested, however, that it is easier to place the thermometer in a similar position in the breast from time to time than it is to do so in the thigh. Therefore, it is recommended that an end-point temperature of 90° C. in the pectoralis major muscle be used for roasting turkey halves to an optimum degree of doneness.